

Event Driven X-ray CCD Detector Arrays for the Reflection Grating Spectrometer on the Constellation-X Mission

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Summary

The Reflection Grating Spectrometer (RGS) on Constellation-X will provide very high spectral resolution in the low energy X-ray band below 2 keV, where most atomic features are located. A baseline value for the RGS of $E/\Delta E > 300$ is planned, with values of $E/\Delta E > 1000$ being discussed as a possible goal for an offplane grating design. Thus, the RGS will complement Constellation-X's X-ray microcalorimeter, which has its highest spectral resolution at energies greater than 2 keV. The Reflection Grating Spectrometer Focal Plane Camera (RFC) reads out the RGS spectra by means of a long array of extended low-energy response, event-driven silicon CCDs (EDCCDs). The current instrument baseline calls for coverage of the X-ray energy (wavelength) range from 0.25 to 2 keV (6 - 50 Å) in an elongated, multi-CCD array. The back-illuminated EDCCD can accommodate these goals, by providing rapid frame rates ($\sim 100\text{Hz}$) at non-cryogenic temperatures ($\sim -20^\circ\text{C}$ or higher), for power requirements $\sim 100\times$ less than for conventional CCDs. Both the RFC detector and array technologies are discussed.

Flight Heritage of RFC

Basic Idea behind Event-Driven CCD

—Pixels with charge above threshold in 3.3 s exposure—
 FI: 26278 out of 1,048,576 pixels - 2.5% BI: 970 out of 1,048,576 pixels - 0.09%
 Key point: Sparsity of pixels containing signal charge in X-ray readout arrays

Cross Sections of FI and BI CCDs

FI device: Poor efficiency, as low energy X-rays are lost due to absorption in gate structure

BI device: X-rays interact efficiently, but electrons are lost to surface traps unless we provide:
 - special back surface processing
 - high electric field to drive electrons toward buried channel

Cross Section of BI CCD Showing Overlayer Structure

Event-Driven CCD Concept and Its Implementation

EDCCD Technology Status

- Gen 1.0 Lot 1 EDCCD
 - 1.5 μm pitch
 - 1.5 μm gate
- Gen 1.5 Lot 1 EDCCD
 - 1.5 μm pitch
 - 1.5 μm gate
 - 1.5 μm gate
 - 1.5 μm gate

Only pixels containing signal charge are read out and digitized in the ADC. All empty pixels are ignored and discarded through the Dump Drain.

X-ray Transmission of Chemisorption Overlayer Structure and Quantum Efficiency of CCD

Response of ACIS BI and Chemisorption CCD

C Carbon and Oxygen lines (same as plot observed by ACIS BI and CC-BI CCDs)

C K line count rate (ACIS/CC) = 1.13

Comparison of Potential Profiles in the Back-Illuminated CCD with Different Surface Treatments

No surface treatment: Native fixed and surface state charge produce potential well for signal electrons near back surface.

Chemisorption surface treatment: Ag layer creates a potential barrier for electrons near the surface, pushing signal electrons away from surface traps. This results in greatly improved charge packet collection, hence the excellent energy resolution shown in the plot above.

Gen 1.5 Lot 1 Wafer

Testing Board with the EDCCD Inserted

Fabrication of Backside Illuminated CCD Imagers at MIT Lincoln Laboratory

CCD Wafer with Center Chemically Thinned

Thinned CCD Laminated to Supporting Wafer

Configuration of Proposed Flight EDCCD Detector

Baseline imager
 Frame Imager (FI): 24 mm x 24 mm
 Frame Store (FS): 2 regions (top and bottom)
 24 mm x 6 mm each
 Basic pixels: 15 microns x 15 microns in FI
 FI format: 1600 x 1600 pixels
 Summing of basic pixels to "superpixels" that match PSF (4 columns x 8 rows)

Clocking
 200 Hz frame rate for 60 x 120 micron "superpixels"
 Serial register rate: 1 MHz per readout

Focal Plane Configuration for Off-Plane Grating

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